FESC
Florida Energy Systems Consortium

Thrust Area 4: Solar (Advanced PV Device Program)

PV Devices Research and Development Laboratory

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Description: The goal from this project is to develop and equip a PV devices R & D laboratory which would then be open to industry, research institutions and academic partners for the purposes of planning, designing, deploying and operating PV systems. The new PV Devices Research and Development Laboratory is a comprehensive suite of scientific tools for the fabrication and characterization of materials and PV devices. The laboratory is located in a new PV laboratory room at FSEC and is designed specifically to reduce time delays associated with transferring technology from the academic research laboratory to industry. Furthermore, the PV laboratory will also facilitate undergraduate and graduate internship programs to train chemists, physicists and engineers in photovoltaic processing, characterization and testing.

Budget: $450,250
Universities: UCF/FSEC

Progress Summary

The goal of this project is to develop and equip a photovoltaic devices laboratory which would then be open to industry, research institutions and academic partners for the purposes of planning, designing, deploying and operating PV systems. Although reliable PV systems are commercially available and widely deployed, further development of PV technology is crucial to enable PV to become a major source of electricity. The current price of PV systems is not low enough for PV electricity to compete with the price of peak power in grid-connected applications and with alternatives like diesel generators in stand-alone applications. It also cannot rival consumer or wholesale electricity prices. A drastic further reduction of turn-key system prices is therefore needed. For these reasons, research and development is crucial for the advancement of PV. Performing joint PV research and addressing well-chosen research issues can play an important role in achieving the critical mass and effectiveness required to meet the sector's ambitions for technology implementation and industry competitiveness.

In the FSEC PV Devices Research and Development laboratory, researchers collaborate with other research teams in using established fabrication and characterization techniques and to develop new in-situ diagnostics tailored for the specific growth and processing steps used in PV manufacturing. The following customized capabilities distinguish FSEC's Devices Research and Development PV Laboratory:

- Dimatix nanomaterials injector printing system,
- Two plasma chemical vapor deposition systems for fabrication of nanorods and controlled size and shape nanostructures,
- Organic/inorganic solar cell fabrication unit using fully enclosed XYZ tabletop normal and ultrasonic spraying system,
- Customized Oriel external and internal quantum efficiency system,
- Oriel Class 3A solar simulator for characterization of novel developed solar cells,

- UV-Vis-NIR spectrophotometers and refractometers for optical analysis and in-situ electro-optical characterization techniques tailored for the specific growth and processing steps used in PV manufacturing like spectroscopic ellipsometry, photoluminescence, photocurrent decay, fourier transform infrared, and Ramen scattering, and indoor and outdoor I-V curve tracers.

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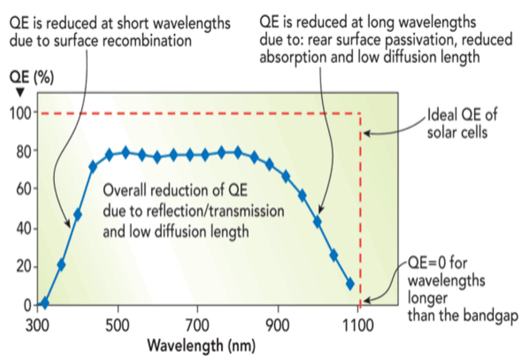
The systems acquired for the PV lab and configured to operate are described in detail as follows.

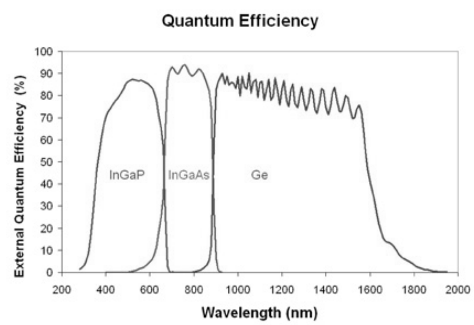
1. Customized Oriel Quantum Efficiency System

The quantum efficiency (QE) system is an essential tool for any laboratory working on PV materials and devices. With the help of Oriel's product engineers, FSEC's researchers have configured this system to measure internal quantum efficiency (IQE). The difference between IQE and EQE is that IQE measurements account for any EM radiation reflected from or transmitted through the PV cell under test. By doing this, one can infer more about the internal workings of the active semiconductor layer, without concern regarding the cell's external optical properties (e.g. anti-reflection coatings). This allows the determination of whether bad performance comes from the active semiconductor itself or simply from high reflection losses at the surface of the cell.

The configuration and operation of this system has included many tasks, including installation of the individual components, optical beam alignment, integration of the LabView based software, several rounds of troubleshooting relating to both hardware and software complications, procedure development, adaptation of test procedures for novel materials and device architectures (e.g. organic PV, multi-junction devices), and development of analytical techniques for processing data. A large part of the effort was placed in customizing this system to measure transmission, absorption, and reflection
measurements of samples, which is required for IQE. Working with Sphere Optics, a manufacturer of integrating spheres, the research group was successful in achieving this new functionality.

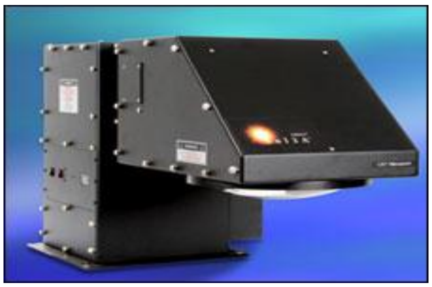

Customized Oriel Quantum Efficiency System



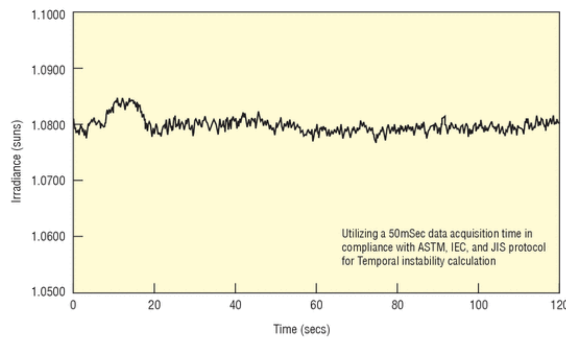


2. Oriel Class 3A Solar Simulator

In the context of PV materials and device research, a solar simulator allows for a dependable measure of device performance under broadband radiation that is spectrally similar to that coming from the sun. The configuration and operation of this system has included the fabrication of a suitable structure for safely mounting the simulator on the laboratory bench, installing individual components (e.g. light source, power supplies, optical filters, etc.), verifying proper beam alignment and light throughput, and testing the unit with actual PV cells with known current-voltage characteristics. The Oriel Sol3A simulator is certified to IEC 60904-9 Edition 2 (2007), JIS C 8912, and ASTM E 927-05 standards for Spectral Match, Non-Uniformity of Irradiance, and Temporal Instability of Irradiance. The Oriel Sol3A simulator use a single lamp design to meet all three performance criteria without compromising the 1 Sun output power and, thus, providing true Class AAA performance. The Oriel Sol3A uses a black non-reflective finish to minimize stray light and incorporates captive screws for all panels requiring user access to facilitate lamp replacement, alignment, and filter changes. See below figure for device and irradiance plot.



Orial Class 3A Solar Simulator

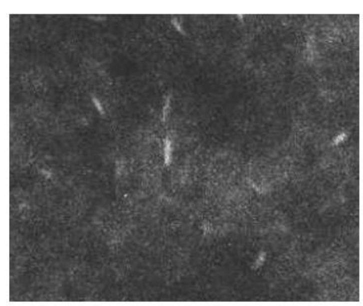


3. Laurell Technologies Spin Processor

Spin coating systems are a common tool in semiconductor fabrication labs and facilities. They allow for a controlled deposition of liquid phase materials. The Laurell Technologies system features an automated dispense system, which allows for better control of the fluid during deposition, therefore better control of the final thickness. This control is very important for PV devices that feature individual layers smaller than 100 nm. The configuration and operation of this system has involved the fabrication of a structure to house the system, installation of individual components (e.g. vacuum pump for the substrate chuck, compressed nitrogen cylinder and regulator for system's pressure inlet), integration of the system software and final verification of proper operation. This system has been used for thin film deposition with different composition, substrates, and microstructures. Some of the key features of the system are:

- Organic and inorganic thin films can be deposited onto any kind of substrates,
- The deposited film can be dense or porous after sintering, depending on requirements for the film,
- The deposition rate and the spinning rate are high,
- The process can be done in under a minute.

Laurel Spin Processor



Structure of the PSDOT/PSS doped with ZnO nanoparticle fabricated with the spin coating system

4. Dimatix DMP-2831 Materials Printing System

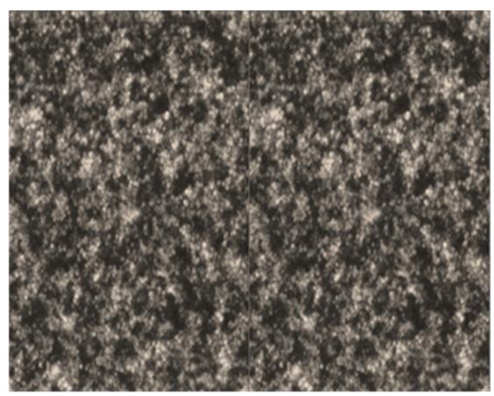
The largest and most expensive item of fabrication equipment is the material printing system (Dimatix, Inc). It is a system used for inkjet- printed quantum dot and nanostructure hybrid PV and TE materials and devices. The system provides a high degree of fabrication accuracy and reliability of fabrication when operated and maintained correctly.

The DMP-2831 is a state of the art printing system which will generate new research capabilities that include experiments with inkjet deposition of organic semiconductors, inorganic solution based semiconductors, and patterned conductive layers. The configuration and operation of this printing system has included the installation of individual components, installation and operation of the system software, fluid transfer to printer cartridge, and troubleshooting to overcome non-jetting nozzles.

5. Spraying system

Inkjet printing is used to create the actual solar absorber, which is the layer in a solar cell in which the sunlight's energy generates free electrons. The inkjet printing technique can be applied to any thin-film materials or organic photovoltaics. For example, cadmium telluride, Si, organic-inorganic materials are absorber layer materials which are being developed for deposition by a liquid precursor. Also, nanoparticulate-based ink is spray-deposited to form a film. Work has successfully produced optically dense thick films—up to 10 micrometers with no cracks. Many solar cell technologies collect freed electrons using a thin layer of transparent conducting oxide rather than metallic grid lines. This work uses special inks, fabricated in our laboratory with spray deposition, to lay down thin, high-quality transparent graphene and carbon nanotubes based layers. Continuing work is expected to improve this technique so that conductivities will rival those of conventionally deposited.

Inkjet Sprayer



Structure of the porous nanoparticle of TiO_2 fabricated with the spraying system